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Satellites Part 1

Colin Redwood introduces readers to satellites in the first of a two-part article.

It's quite a few years since I looked at satellites in the *What Next* column and several readers have contacted *PW* asking for help in getting started. This month, therefore, I'm going to start with some basics so that you can begin to receive signals from amateur satellites with little more than a VHF/UHF handheld. Next month, I'll look at conducting QSOs through satellites.

Satellite Orbits

Commercial satellites, such as those used for domestic satellite television, are in what is known as geostationary orbits. This means that they stay in the same position in space relative to the earth, so receiving dishes on our homes don't need to move and can continuously point at the same part of the sky and receive television pictures from the same satellite all the time.

Unlike most of their commercial counterparts, amateur radio satellites are not in geostationary orbit. This means that as they orbit the earth, their location in the sky relative to the earth is constantly changing. Much of the time, an amateur radio satellite will be below our horizon, over another part of the earth, so that we don't even have a line of sight view of it and hence are unable to contact it on the VHF or UHF bands that are used for satellite operations. Although at first sight this may seem to be a drawback, it does, in fact, have some significant advantages. The main advantage is that different parts of the world can use the satellite for contacts as the footprint (the area of the world able to 'see' the satellite at any one time) constantly changes. Most areas of the world will get the opportunity to use the satellite for at least some of the time.

The height of the satellite above the earth is also important. The higher it is, the greater the area of the earth in the footprint. Some satellites have an elliptical orbit so that at times when the satellite is relatively low above the earth the footprint is small, while when it is farther out into space, the footprint is very much larger.

Satellite Predictions

Because amateur satellites are not in geostationary orbits, we need to know when each satellite will be visible from where we are on earth. I like to think of these predictions as a bit like a bus timetable. To interpret a bus timetable, you need to know at which bus stop you are waiting and which bus you are waiting for. Just as there are separate timetables for each bus route with some buses running more often than others, there are separate predictions for each satellite.

If I wait at a bus stop, I'll be able to see the bus for a while as it comes along the road towards the bus stop. To do this, I'll need to know from which direction the bus is coming. If I don't actually get on the bus, I'll also be able to see it for a while as it drives along the road away from the bus stop. So there is a period of time that I can actually see the bus, from when it comes into view in one direction until it finally disappears from sight in another. Unlike buses, which may be late, cancelled, or occasionally early, satellites are very punctual.

The Jargon

In order to interpret satellite predictions, we need to become familiar with some of the key pieces of satellite jargon.

Orbits and Passes

Each time a satellite goes round the earth is called an orbit. Each time the satellite's footprint passes within range of a particular point on the earth is referred to as a pass. So going back to our bus timetable, only those trips that actually come past our bus stop are passes as far as we are concerned.

AOS

AOS stands for Acquisition of Signal. It's the time at which the signal from the satellite can be expected to be audible (assuming there are no visible obstructions). This is the satellite equivalent of when you can start to see the bus approaching your bus stop.

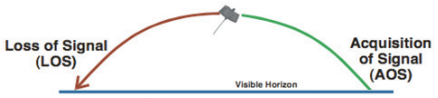

Fig. 1: Acquisition of Signal (AOS) and Loss of Signal (LOS). A satellite will only be audible when it is above the horizon between AOS and LOS.

LOS

LOS stands for Loss of Signal. It's the time at which the signal from the satellite can be expected to cease to be audible (again assuming there are no visible obstructions). This is the satellite equivalent of when the bus disappears from view from your bus stop.

At best, you can only hear a satellite between the AOS time and the LOS time, **Fig. 1**. The angle of the satellite above the horizon and thus the apparent height above the horizon is also a consideration. The predictions all assume that the earth is a smooth sphere. If there are hills or other obstructions like houses and trees between the location of your particular station and the horizon, AOS may be after the predicted time and LOS may be before the predicted time. Unless the satellite is at least a few degrees above the horizon, you may miss out completely on some passes.

AOS and LOS Azimuths

Like a bus going along a road, during a satellite's pass the satellite will move across the sky. The AOS azimuth (or bearing) is the angle (in degrees) clockwise from north that the satellite will appear above the horizon. Likewise, the LOS azimuth (or bearing) is the angle from north that the satellite will disappear below the horizon. Knowing the AOS and LOS azimuth is particularly important if you are using a directional antenna so that you can point it in the correct direction and move it to continue to point at the satellite during the pass until the signal is lost.

Maximum Elevation

The maximum elevation gives information on how high in the sky the satellite will reach. This is a particularly important parameter if you cannot see to the horizon from your location. If the satellite's pass only reaches 10° above the horizon, then local obstructions are likely to block the signals from the satellite to your station. To start with, I would look at passes with a maximum elevation of at least 20° although

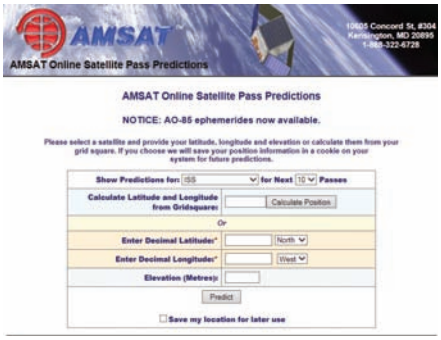

Fig. 2: A screen shot of AMAST's online Satellite Pass Predictor. Select a satellite, enter your locator or latitude and longitude, then press 'Predict'.

in an urban environment even this is quite low. You may find that passes of 35° to 40° or more may be required at your location for solid copy.

Location

Before you can do any satellite predictions, you need to know your location. If you already know your six-character IARU locator (sometimes called Maidenhead locator or Grid), then great. If you don't, then I think the easiest way to find it is to use F6FVY's website. Just move the red locator (centred on Paris, France when you start) to your location. If you are on a border between two locators, don't worry, using either is unlikely to materially affect the results. For almost all of the British Isles, the locator will start either IO or JO followed by two numbers, followed by another two letters. The centre of Birmingham, for example, is IO92BL.

http://qthlocator.free.fr/index.php

Getting Hold of Predictions

You'll now need to know how to get hold of satellite predictions. There is a variety of programs available from various sources (including Amsat, the Amateur Satellite group). If you decide to use a program, don't forget to update the Kepler elements (KEPS). Most programs and other sources will show the times in UTC/GMT (even during British summer time). To get started, I suggest using the Amsat website, **Figs. 2** and **3**, because it already has up-to-date Kepler elements.

www.amsat.org/amsat-new/tools/predict

Uplink and Downlink

The uplink is the transmission from earth up to the satellite while the downlink is the transmission from the satellite down to earth. The various satellites operate on different frequencies. A number of satellites use an uplink frequency in the 2m band and a downlink frequency in the 70cm band. While SSB and CW used to be the most common modes for making contacts through amateur satellites,

AMSAT Online Satellite Pass Predictions - SO-50

View the current location of SO-50

Date (UTC)	AOS (UTC)	Duration	AOS Azimuth	Maximum Elevation	Max El Azimuth	LOS Azimuth	LOS (UTC)
06 Dec 15	21:12:14	00:10:02	149	8	109	60	21:22:16
06 Dec 15	22:49:32	00:14:19	203	51	125	44	23:03:51
07 Dec 15	00:30:15	00:14:16	247	38	330	42	00:44:31
07 Dec 15	02:12:41	00:12:56	285	18	342	51	02:25:37
07 Dec 15	03:54:58	00:12:54	310	18	6	76	04:07:52
07 Dec 15	05:36:05	00:14:08	318	39	39	114	05:50:13
07 Dec 15	07:16:46	00:14:02	315	48	238	159	07:30:48
07 Dec 15	08:58:30	00:09:22	298	7	259	214	09:07:52
07 Dec 15	21:36:02	00:12:40	174	19	117	51	21:48:42
07 Dec 15	23:15:01	00:14:36	222	83	326	42	23:29:37

Fig. 3: Predictions for ten passes of SO50 in early December 2015.

in recent years many, mainly smaller, satellites have been put into orbit that use FM on both the uplink and downlink frequencies. These can be a good choice for beginners to satellite operation because many amateurs will already have a basic 2m/70cm FM handheld transceiver although some of the SSB satellites can actually be easier to hear when you have a limited antenna system.

What's Up

Now you know how to interpret the satellite predictions, you need to decide which satellite to use. Your choice will probably be determined by the equipment we have. There's another reason to visit the Amsat website – this time to find out the latest status of the various amateur satellites, **Fig. 4**.

www.amsat.org/status

For those satellites with their names underlined, there is a link to a page with some basic details about the satellite. In particular, it gives the frequencies and modes used for uplink and downlink. In addition, the correct CTCSS tone (called the pilot tone) is also given where needed.

For a simple way to start, I suggest choosing the SO-50 satellite (also known as Saudisat 1C). The downlink frequency is on 436.795MHz FM at the centre of the pass. Alternatively, you can try listening for the International Space Station (ISS) APRS signals on 145.825MHz FM or contacts through the FUNcube (AO73) on 145.950 – 145.970MHz SSB during night passes and weekends. During the day, AO-73 transmits a high power beacon on 145.935MHz SSB, which may be simpler to hear with a fixed, vertical antenna.

Doppler Shift

You'll need to take account of what is called Doppler shift during the pass of a

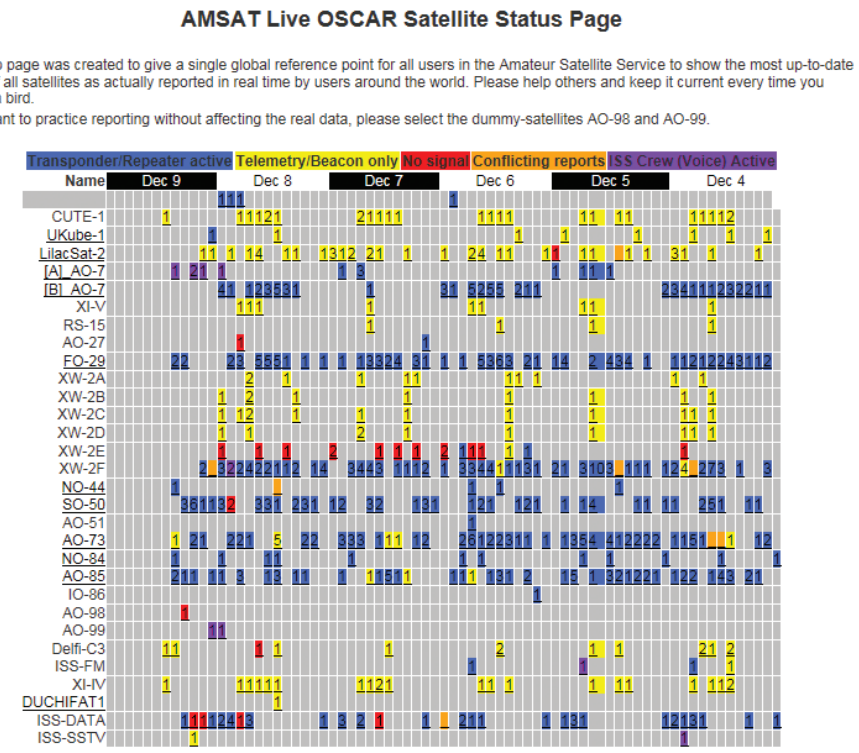

Fig. 4: The current status of amateur satellites. For those satellites with their names underlined, there is a link to a page with the uplink and downlink frequencies and modes.

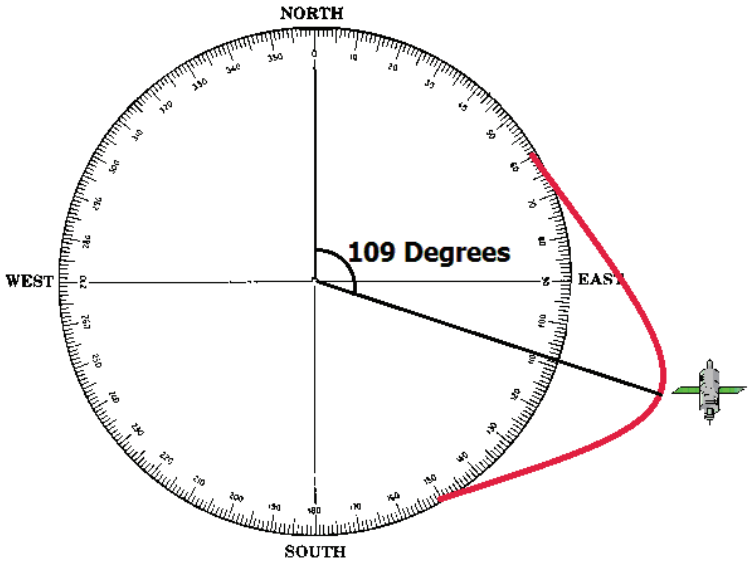

Fig. 5: A visualisation of the satellite pass described in the text.

Fig. 6: Listening for a satellite on a 2m downlink with a small portable Yagi antenna.

satellite. As the satellite approaches it will be higher in frequency and as it moves away it will be getting lower in frequency. Taking the SO-50 satellite as an example, at AOS the satellite will be on 436.805MHz, dropping down to the nominal frequency of 436.795MHz at the highest point of its pass and then further down to 436.785MHz or below. You will need to be able to tune your receiver so that you can hear the other stations clearly. You may find it helpful to store the relevant frequencies in adjacent memories.

Even if your equipment can't tune in 5kHz steps, it will almost certainly be able to tune in 12.5kHz steps, so you'll probably be able to hear SO50 on 436.800MHz for at least part of the pass. On a good high-elevation pass of 60° or more, it might even be audible on a 'rubber duck' antenna or half-wave whip. I would suggest trying several passes with different maximum elevations to find which yield the best results for your particular location and antenna. You may find that tilting your handheld between vertical and horizontal will improve reception, particularly when the maximum elevation is above 45°.

Antennas

You'll certainly need to be prepared for weak signals from satellites. They are generally very much weaker than signals from the local 2m or 70cm FM repeater so you will need to open the squelch. I would also suggest using an antenna with gain to make the most of the weak signals. The 'rubber duck' antenna that comes with your handheld will allow a strong downlink signal from the ISS on 145.825MHz to be heard if it is operational, but you may struggle to hear passes of many satellites except under the best conditions.

Feeder Loss

With weak signals, feeder loss can be quite significant so I would suggest using a low loss feeder, particularly if the distance from the antenna to the transceiver is more than a few metres. A low noise preamplifier may be worth trying if you have one. Maximum benefit will be obtained by mounting this at the antenna rather than having it in the shack.

Predictions in Practice

Having looked at the various parameters that make up a pass, it's time to put them into practice! I am going to look at the first line of the predictions in Fig. 3.

On December 6th 2015 at 21:12:14UTC, the SO50 satellite appeared above the horizon just east of south (149°). It moved round the sky towards the north via the east and was at its highest at just 8° above the horizon, slightly south of east (109°), before dropping down to below the horizon in the north-east (60°) at 21:2:16, **Fig. 5**. So the satellite was above the horizon for ten minutes and two seconds. The highest point was reached half-way through the pass. In reality, with a maximum elevation of just 8° above the horizon, it's unlikely that it would have been heard by many stations due to local obstructions.

Hopefully this example will have helped readers visualise the path of the satellite in the sky. You may find that taking a compass and a protractor outside and working through the example will help further.

The next pass, on December 6th 2015 at 22:45:32UTC, was a much more useful pass because SO50 reached 51° above the horizon and was thus far less affected by local obstructions. At home I find that I need passes that are about 15° or more above the horizon to hear the satellite on a small dual-band collinear antenna about 8m above the ground although this varies depending on the part of the sky that the satellite is in.

Give It a Try

I would certainly encourage readers to have a go at listening. If you don't have a 70cm receiver but have a 2m receiver, then try listening for the ISS or the AO73 FUNcube, **Fig. 6**. If you don't succeed with one pass, try a later pass or a different satellite or band. You'll also read more about satellite operation every month in **Tim Kirby's** VHF column.

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Satellites Part 2

Colin Redwood G6MXL completes his introduction to using amateur satellites.

Last month I looked at the various techniques to receive signals from amateur radio satellites on their downlink frequencies, including predicting the times and direction of satellite passes. These are essential skills to acquire before thinking about trying two-way contacts by transmitting on satellite uplink frequencies. This month I am looking at improving your reception and then making contacts through satellites.

Weak Signals

Those readers who tried receiving signals on satellite downlink frequencies using the techniques that I described last month will hopefully have heard some signals from at least one satellite. In many cases, the signals will have been very weak with lots of noise, often making it difficult to copy callsigns. To improve reception, an antenna with some gain will help. I'd also suggest re-reading last month's column and consider using lower loss feeder and perhaps a preamplifier. It might be a good idea to check that there hasn't been any water ingress into feeder given the high level of rainfall over the winter.

Preamplifier

I mentioned last month that a preamplifier can be useful in overcoming feeder loss on receive. If possible, try to mount it close to the antenna. If this isn't feasible, then try it in the shack. If it shows a worthwhile improvement in the shack, then you'll see a bigger improvement if you mount it close to the antenna. Wherever you locate it, be particularly careful never to transmit directly into an un-switched preamplifier – the transistors in them are particularly sensitive and can easily be damaged.

Antennas

Over the years, Arrow Antennas have expanded their range of antennas for portable satellite use. Some of them include built-in diplexers. I've used one that has three elements on 2m and seven elements on 70cm. They are certainly popular with satellite operators. I have also used mine to make some terrestrial contacts on a couple of occasions. According to Arrow, it has a forward gain of about 10.3dB on 70cm and 4.6dB on 2m. It is sufficiently compact to just fit into a small overnight suitcase. As these antennas come from the US, you'll also have to pay import VAT and the Post Office handling charge on top of the base price.
www.arrowantennas.com

Another popular option for portable operation is the Elk 144/432MHz log periodic, which is available from the AMSAT-UK shop, below.
http://shop.amsat.org.uk

Diplexers

I suspect the term diplexer will be a new one to some readers. Diplexers can be used in two different ways. In the role I am describing here, it enables a 2m/70cm dual-band transceiver with a single antenna socket to use a separate antenna for each band, such as the Arrow antenna I mentioned above. Alternatively, diplexers can enable a single antenna such as a dual-band collinear for 2m and 70cm to be used with a single transceiver with separate antenna sockets for 2m and 70cm, or separate transceivers, **Fig. 1**.

Before using a diplexer, it is important to understand its parameters. The components used in the construction of the diplexer will have limits to the power that they can handle. If you are sharing a single antenna between two transceivers, it is absolutely essential that the diplexer provides enough isolation between the two ports. If there is insufficient isolation, then some of the transmit signal will get into the receiver front-end on the other transceiver and potentially overload or even damage the sensitive front-end components.

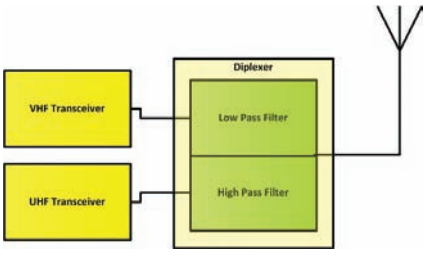

Fig. 1: Using a diplexer to enable a dual-band antenna to be shared with two transceivers.

Antenna Polarisation

As the satellite appears over the horizon, you'll need to rotate the antenna between vertical and horizontal polarisation to find the best result because you cannot predict the polarisation of the signals from the satellites. Starting with the antenna at 45° can be a good technique to at least hear the satellite as early in the pass as possible. For more advanced operators, using an antenna with circular polarisation can help. For some satellites such as AO-85, in particular, you may find it advantageous to twist the antenna through 90° when you transmit and then twist it back to receive. Full duplex really helps here so that you can hear your own signal back through the satellite and work out the best polarisation.

Transmitting

It could be easy to get the impression that highly sophisticated and expensive equipment is needed to enjoy satellite QSOs. It is possible to get started with little more than a dual-band handheld FM transceiver and a small combined 2m and 70cm Yagi that can even be handheld in the first instance. You'll probably have read of such contacts in **Tim Kirby G4VXE's** VHF column.

Almost all satellite contacts are made by transmitting from earth to the satellite (the uplink) on one amateur band and receiving the satellite (the downlink) on a different amateur band. Most satellites operate in the satellite parts of the 2m and 70cm bands. The key requirement for both stations involved in a contact through a satellite is to be able to transmit on one band (2m, for example) and receive on a different band (such as 70cm).

The International Space Station (ISS) is a notable exception, when from time to time there are amateur radio operators on board such as at the present time with UK astronaut **Tim Peake** who holds the US callsign **KG5BVI**. Most operations have downlinks and uplinks on the same frequency using FM for either voice or Slow Scan Television (SSTV), **Fig. 2**.

Transceivers

A number of transceivers allow transmission on one band and reception on another. Even some portable handheld transceivers provide this facility. Examples

Fig. 2: A Slow Scan TV picture received from the ISS on 2m.

Fig. 3: The Kenwood TH-D72e dual-band FM transceiver can receive on one band while transmitting on the other band, making it ideal for FM satellites.

include the Kenwood TH-D72e, **Fig. 3** and its predecessor, the TH-D7e. This makes them particularly suitable for satellite contacts, enabling contacts to be made with stations in another continent using just a dual-band heldheld transceiver and a small portable antenna.

CTCSS

A number of the FM satellites require the use of CTCSS tones on their uplinks, similar to ground-based repeater systems. You'll need to program these into your transceiver before the pass. I would suggest using some of the multitude of memories available on modern transceivers for each satellite. Some satellites such as SO-50 require an initial CTCSS tone on one frequency (74.4Hz) to start the satellite's transmitter for ten minutes, then a 67Hz tone during contacts. SO-50 has an uplink frequency of 145.850MHz FM and a downlink frequency of 436.795MHz FM, with both frequencies subject to Doppler shift. On a long pass, you may need to send a 74.4Hz CTCSS tone a second time.

If you have an older transmitter without built-in CTCSS, it's worth checking to see whether an optional board is still available from the manufacturer or on the second-hand market. Alternatively there are several suppliers of CTCSS tone kits, including CS Technology. Their website, **Fig. 4**, is at the URL below.
www.cstech.co.uk

Linear Transponding Satellites

Unlike the FM satellites, satellites with

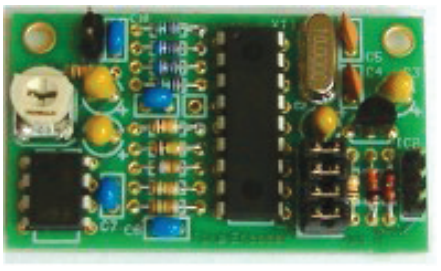

Fig. 4: The CTCSS Board from CS Technology measures just 49 x 29mm.

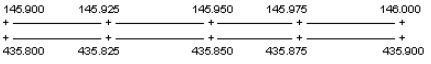

Fig. 5: Non-inverting transponder.

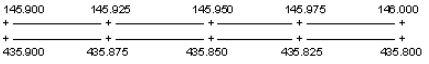

Fig. 6: Inverting transponder.

linear transponders don't operate on a specific frequency but take a fairly small range of frequencies in one band, convert them and retransmit them on a similar small range of frequencies on another band (a bit like a transverter). The range of frequencies involved is known as the passband of the transponder. These transponders can handle a number of SSB and CW contacts simultaneously (a bit like you do when you receive multiple PSK31 signals).

Inverting and Non-Inverting Transponders

If you are using a satellite with a transponder, then you'll need to know whether it is inverting or non-inverting. Non-inverting transponders, **Fig. 5**, receive upper side band (USB) signals at the high end of the uplink pass band and these appear as USB signals at the high end of the downlink pass band. With an inverting transponder, **Fig. 6**, to receive that same high end USB signal, you would transmit a lower side band (LSB) signal at the lower end of the uplink passband.

Transceivers for Transponders

Transceivers designed to handle non-inverting and inverting transponders will automatically adjust the uplink frequency either up or down as you adjust the downlink frequency for Doppler shift. Current multimode transceivers include Kenwood's TS2000/TS2000X models and Icom's IC-9100, **Fig. 7**. You may find the discontinued Yaesu FT-726, FT-736 and FT-847 or Icom IC-910H models on the second-hand market, all of which have facilities for transponding satellites. Each of these transceivers can also be used for contacts through FM satellites, although some will need an additional CTCSS board if it is not already equipped. If your transceiver supports

Fig. 7: Icom's IC-9100 is a popular transceiver for satellite operators.

computer control, you may want to look at using the SATPC32 software, which will automatically work out the Doppler shift on both uplink and downlink as you tune around the transponder.

Low Power for Transponders

It is important not to use more power than needed when transmitting into a linear transponding satellite. The more power you use, the greater the power the satellite will use when it retransmits your signal on the downlink frequency and hence the greater the drain on the on-board batteries. The on-board batteries are charged by solar cells only at times when the sun illuminates them. For charging to take place, the satellite needs to be on the sunny side of the earth and, even then, the solar panels must not be in the shadow of the body of the satellite itself.

It is good practice when using linear transponder satellites to listen for the satellite beacon or telemetry (data on the condition of the satellite) frequencies and to make sure that your transponded signal is no stronger than the beacon or telemetry.

Delay

When making contacts through a satellite well out into space – mostly linear transponders in highly elliptical orbits – it takes time even for a radio signal travelling at the speed of light to reach the satellite and return to earth. If you are listening with headphones for your signal being transmitted back to earth (a good practice), as you speak you will hear your voice delayed by a fraction of a second. There is a natural tendency to speak slower in the expectation that the sound of your voice will catch up. Because it doesn't, you may find yourself speaking progressively slower! In these circumstances, I find it best to reduce the volume on the receiver while I am transmitting.

Operating Techniques

Compared with terrestrial contacts through repeaters, contacts through satellites are relatively brief. Chatting about your holiday for ten minutes on a single channel FM repeater satellite will mean that nobody else in Europe gets a chance to use the satellite for a whole pass. So you really need to get used to keeping 'overs' short and to the point (limited, generally, to an exchange of callsigns, reports and locators).

It is worth keeping an eye on forthcoming DXpeditions and on the DX Cluster because sometimes some rare DXCC entities can be worked via satellites.

Logging

If you are operating portable with a handheld antenna, you are likely to run out of hands when trying to operate the transceiver, microphone PTT and holding or adjusting the antenna so that trying to log as well (no matter whether by computer or paper) is just impossible. Making an audio recording of your contacts can be a simple solution so that you can complete your log entries after the pass.

If you use Logbook of the World (LoTW), you'll need to add two extra fields to your logs for satellite contacts, one to identify that it is a satellite contact and the second to identify the actual satellite used. Full details can be found in the document below.

http://tinyurl.com/gpkbwuf

Rotators

Once you get addicted to amateur radio satellites, you'll find that there are numerous ways of improving your station still further. I've already mentioned some, such as using low loss feeder and preamplifiers. You may also want to explore the use of electrical rotators that not only move directional antennas around 360° (known as azimuth rotators) but also up and down (known as elevation rotators). Combined azimuth and elevation rotators are also available to keep antennas pointing at the satellite at all times during the pass. Some can integrate with satellite tracking software to free you up to concentrate on operating during a pass.

Join AMSAT

If you make use of amateur radio satellites, please be prepared to pay something to the organisation that designs, builds and launches them – AMSAT. To join AMSAT, a minimum donation of £15 per year is required (the maximum is as much as you can afford). Members receive *Oscar News* electronically or, for a small supplement, a printed copy. AMSAT also supply a range of items such as tracking software, rotator interfaces, preamplifiers, antennas and books – check their website for current availability.

http://amsat-uk.org

Not Interested

No doubt there will be some readers who are not interested in amateur satellites. To these readers, I'd simply ask that you show consideration to your fellow amateur radio enthusiasts and avoid transmitting in the satellite parts of the bands. For example, the 145.800MHz to 145.999MHz segment of the 2m band is reserved for satellite QSOs. This part of the band can seem very quiet even when a satellite is passing overhead.

Finally

And finally, don't forget to keep Tim Kirby G4VXE posted with news of your satellite contacts. He will be delighted to hear from you.